International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 9, Issue 6, Dec 2019, 981–990

INVESTIGATION OF CHEMICAL ABSORPTION EFFECTS ON MECHANICAL PROPERTIES OF THE KEVLAR/CARBON FIBER REINFORCED HYBRID COMPOSITES

M. RAMARAO[1], K. L. NARAYANA[2] & B. DURGA PRASAD[3]

[1]*Research Scholar, Department of Mechanical Engineering, JNTUA, Ananthapuramu, Andhra Pradesh, India*

[2]*Professor, Department of Mechanical Engineering, SVCET, Chitoor, Andhra Pradesh, India*

[3]*Professor, Department of Mechanical Engineering, JNTUACEA, Ananthapuramu, Andhra Pradesh, India*

ABSTRACT

The demand for using synthetic fiber reinforced composites in automotive and aerospace industries is increasing day by day. Combination of two or more fibers for fabricating composite samples alter the mechanical properties of the synthetic fiber reinforced composites. The present study investigates the effect of chemical absorption with NaCl, HCl, H_2SO_4 on the mechanical properties of Kevlar/carbon fiber reinforced hybrid composites. The composites are prepared by using Hand layup technique. The fabricated composite samples are soaked in chemicals and these soaked samples are tested for the mechanical properties like tensile and flexural properties. The results of these tests revealed that the chemical absorption alter the mechanical properties of the hybrid composites.

KEYWORDS: Carbon, Kevlar, Epoxy, Hybrid, Mechanical Properties & Chemical Absorption

Received: Jun 05, 2019; **Accepted:** Jun 25, 2019; **Published:** Dec 04, 2019; **Paper Id.:** IJMPERDDEC201982

Original Article

1. INTRODUCTION

The demand for using synthetic fiber reinforced composites in automotive and aerospace industries is increasing day by day. The demand for these composites increased due to their excellent properties when compared to the existing materials. Synthetic fiber reinforced composites possess high strength, high modulus to density ratio, less weight as well. The property like high modulus to density ratio of these synthetic fiber reinforced composites lead the researchers to work on the hybrid composites by blending two or more fibers for fabrication of composites such that the properties of the composite can be altered [1–3]. Exposing FRPs to water, moisture, humidity, alkalis and other solutions with various temperatures will alter the physical and chemical properties of the polymers [4]. Exposing to these environments degrades the fiber matrix interface and plasticizes the matrix. Exposure to environments induces the physical and chemical processes of degradation in the polymer composites [5]. Therefore, it is essential for the engineers and scientists to know the behavior of the FRPs under various environmental conditions to predict the service life of the polymer composites for various applications.

Selzer and Friedrich [6] investigated on the effects of moisture on the mechanical properties of the polymer composites. Moreover, the effects of different matrices on these moisture effects were also investigated in their work. Panthapulakkaland Sain [7] observed the mechanical, water absorption and thermal properties of hemp/glass fibre reinforced hybrid composites and concluded that inclusion of glass fiber enhanced the mechanical thermal and water absorption properties. Romanzini et al. [8] investigated on the

effects of fibre content on the mechanical and dynamic mechanical properties of glass/ramie polymer composites and concluded that the incorporation of glass fiber into the hybrid composites improved the mechanical properties. Ramesh et al. [9] investigated on the sisal-jute-glass fibre reinforced polyester composites to know their fiber content effects on the mechanical properties. The results from the work specified that incorporation of glass fiber enhanced the mechanical properties.

In the present work, the composites were prepared by combining both Kevlar and carbon fibers each of 4 layers to obtain a thickness of 5 mm. The fabricated hybrid composite samples were soaked in acids to know their effects on the mechanical properties. Exposure to environmental conditions, moisture absorptions and acidic conditions alters the physical and chemical properties and degradation nature in the polymer composites. For which, both tensile and flexural properties were tested on the soaked and dried samples and compared the results.

2. MATERIALS AND METHODS

2.1 Materials

The present study used commercially available Epoxy LY 556 and Hardener HY 951, since these resin cures even at room temperature. Chemicals like NaCl, HCl and H_2SO_4 supplied by Ram Composites, Hyderabad were used for the chemical treatments of hybrid composites. Two synthetic fibers were used in the present study for preparation of hybrid composites, Kevlar fiber k-29 of plain weave type with a thickness of 0.61 mm and at 485GSM; carbon fibers of twill weave type with a thickness of 0.5μm and at 420 GSM.

2.2 Fabrication of Hybrid Composites

Fabrication of the composite samples starts with the fabrication of the mould. Moulds of dimensions 325x300x5 mm^3 were fabricated using the steel sheets. The moulds have a provision at one end to remove the fabricated composite laminate, such that the composite laminate can be removed easily. The first step in fabricating the composite laminate is to apply mould releasing agent, moiller film is coated over the surface of the mould. Later, the synthetic fibers both Kevlar k-29 and carbon fibers are cut with dimensions of 325x300 mm^2. The matrix was prepared by mixing both epoxy and hardener with a ratio of 10:1 and is stirred for 10 min using mechanical stirrer. A thin layer of the prepared matrix is poured over the mould, later the fibers are placed over one other with a stacking sequence. A total of 8 layers were placed, each of 4 layers with one over the other by rubbing the matrix on each layer. Both matrix and fibers were placed into the mould till a uniform thickness of 5 mm is obtained. The steps for preparation of the composite laminates are shown in figure 1.

Figure 1: Fabrication steps of Composite Laminates using Hand Layup Technique.

2.3 Solution Preparation

The fabricated hybrid composite samples were soaked in chemicals like NaCl, HCl and $H_2SO_4$for two weeks each. All the solutions are prepared with 3% concentrations and the chemicals used in the present study is shown in figure 2. All the solutions are mixed in diluted water to form a 3% concentrated solution. The prepared solutions are kept in beakers and the samples are soaked in the solutions for two weeks to know their hygrothermal effects.

Figure 2: Chemicals used in the Present Study to Soak the Composite Specimens.

2.4 Testing of Hybrid Composites

The fabricated composite samples are to be tested for both tensile and flexural tests. The composite laminates are cut according to the ASTM standards and for each test three samples were cut from the composite laminate. The hybrid composite specimens before tests are shown in figure 3.

Figure 3: Composite Specimens cut with Standard Dimensions from Composite Laminates.

2.5 Tensile Strength Measurement

The hybridcomposite samples are tested for tensile strength as per the ASTM D 638 standards. The dimensions of the tensile test sample are with dimensions of 165x19x5 mm^3. Gauge length of 57 mm and grip length of 28.25mm. Tensile test are performed on Universal Testing Machine (UTM) at a cross head speed of 2 mm/min with 50% relative humidity and at room temperature. A total of three samples are tested for each criteria and an average is calculated and projected.

2.6 Flexural Strength Measurement

The hybrid composite samples are tested for flexural strength as per the ASTM D 790standards. The dimensions of the flexural test samples are with dimensions of 127x12.7x5 mm^3. Flexural test are performed on Universal Testing Machine (UTM) at a cross head speed of 5mm/min with 50% relative humidity and at room temperature. A total of three samples are tested for each criteria and an average is calculated and projected.

3. RESULTS AND DISCUSSIONS

This section describes the test results of the mechanical properties of the hybrid composite samples. Both the tensile and flexural tests are tested on the fabricated Kevlar/carbon fiber reinforced hybrid composites.

3.1 Tensile Strength

The results of the tensile properties of the Kevlar/carbon fibers reinforced hybrid composite samples are tabulated in Table 1. Three chemicals are involved in the present study to immerse the test samples and one sample in dry condition.

Table 1: Chemical Absorption Effects on Tensile Properties of Kevlar/Carbon Fiber Reinforced Hybrid Composites

Treatment	Tensile Strength (N/mm2)	Tensile Modulus (N/mm2)	Elongation (mm)	Tensile Yield Strength (N/mm2)
Dry	250	1012	16	225
NaCl	220	870	16.5	180
HCl	240	950	16.5	215
H_2SO_4	235	850	17.5	210

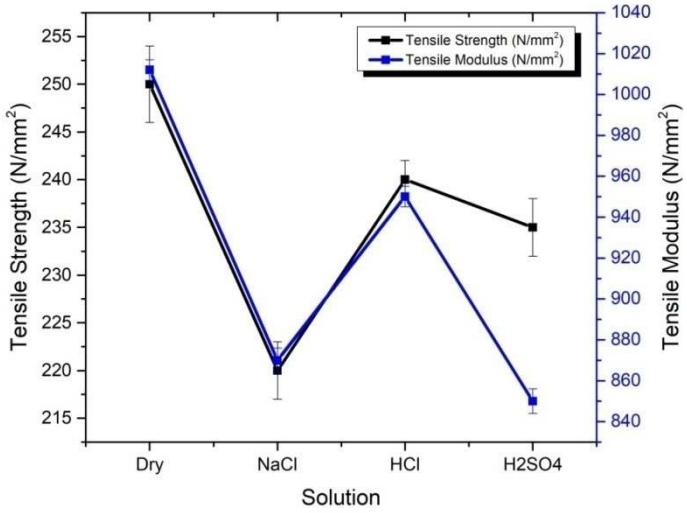

Figure 4: Chemical Absorption Effects on Tensile Strength and Modulus of Hybrid Composites.

Figure 4 represents the solution absorption effect on tensile strength and tensile modulus of the Kevlar/carbon fiber reinforced composite samples. From the figure 4, it was noted that the tensile strength of all the chemical absorption were less when compared to the dry condition. There is a decrement of 12 %, 4 % and 6 % of tensile strength for sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4), respectively. Whereas, the tensile modulus decrement was observed as 14%, 6% and 16 % for Sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4), respectively. Similar results were observed by other researchers mentioning that the dipping of composites in acidic solutions reduces the tensile properties of the composite samples [10–12]. Soaking of these hybrid composites in acids made the composites to decompose easily after their retirement.

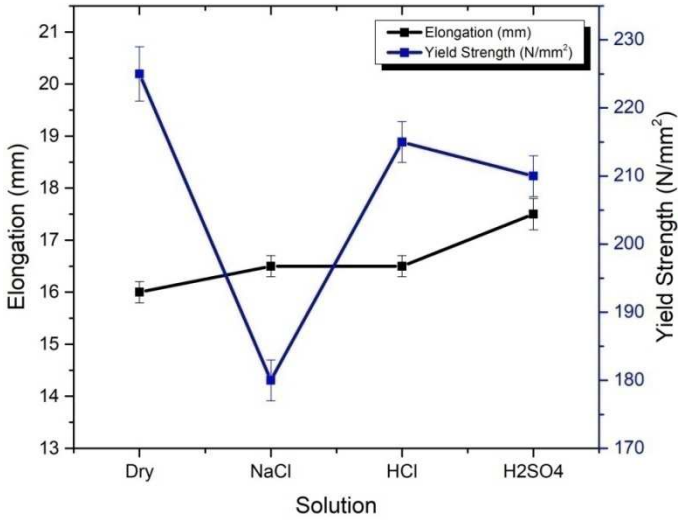

Figure 5: Chemical Absorption Effects on Elongation and Yield Strength of Hybrid Composites.

Figure 5 represents the solution absorption effect on elongation and yield strength of the Kevlar/carbon fiber reinforced composite samples. From the figure 5, it was noted that the elongation of all the chemical absorption were more when compared to the dry condition. Soaking of hybrid composites made the composites ductile in nature as is observed from the results. There is an increment of 3 %, 3 % and 9 % of elongation for sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4), respectively. Whereas, the tensile yield strength decrement was observed as 20 %, 4% and 6 % for Sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4), respectively.

3.2 Flexural Strength

The results of the flexural properties of the Kevlar/carbon fibers reinforced hybrid composite samples are tabulated in Table 2. Three chemicals are involved in the present study to immerse the test samples and one sample in dry condition.

Table 2: Chemical Absorption Effects on Flexural Properties of Kevlar/Carbon Fiber Reinforced Hybrid Composites

Treatment	Flexural Strength (N/mm2)	Flexural Modulus (N/mm2)	Deflection (mm)	Flexural Yield Strength (N/mm2)
Dry	124	7000	5.9	38
NaCl	320	6500	6.5	85
HCl	310	5800	6.4	95
H_2SO_4	290	9000	6.8	125

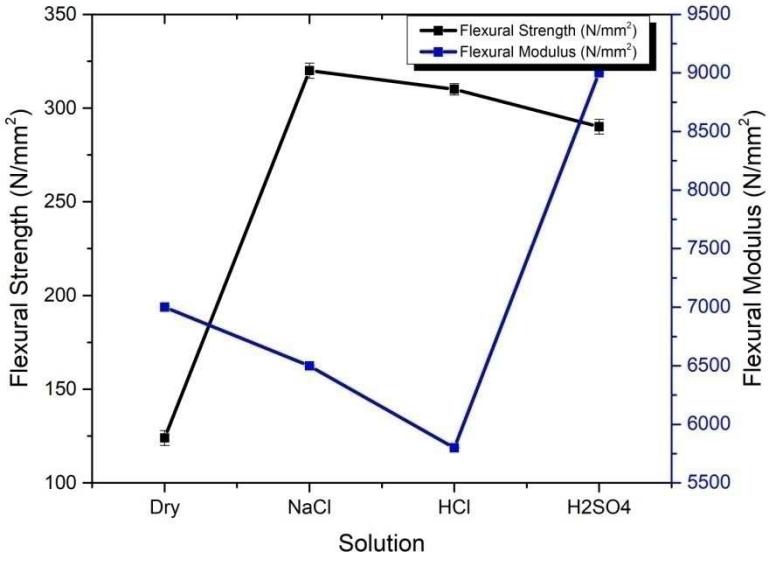

Figure 6: Chemical Absorption Effects on Flexural Strength and Flexural Modulus of Hybrid Composites.

Figure 6 represents the chemical absorption effect on flexural strength and flexural modulus of the Kevlar/carbon fiber reinforced composite samples. From the figure 6, it was noted that all the flexural strength of composite samples soaked in Sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4) was increased when compared to the dry samples. There was an increment of 158 %, 150 % and 133 % for Sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4), respectively. Whereas, the flexural modulus decrement was observed for both Sodium chloride (NaCl) and Hydrochloric acid (HCl) with a decrement of 7 % and 17 % respectively, but there is an increment of 28 % for Sulfuric acid (H_2SO_4).

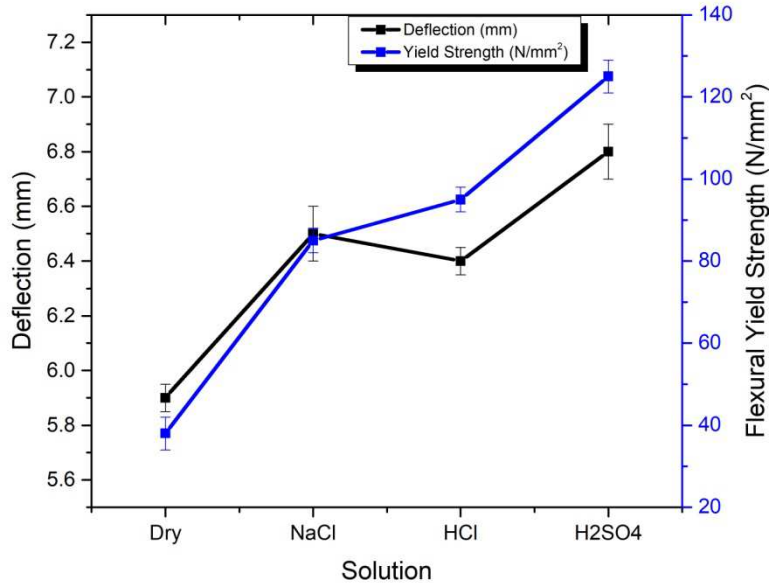

Figure 7: Solution Absorption Effects on Elongation and Yield Strength of Hybrid Composites.

Figure 7 represents the chemical absorption effect on deflection and yield strength of the Kevlar/carbon fiber reinforced composite samples. From the figure 7, it was noted that the deflection and yield strength of all the chemical absorption were increased when compared to the dry condition. Soaking of hybrid composites made the composites ductile

in nature as is observed from the results. There is an increment of 10 %, 8 % and 15 % of deflection for sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4) respectively. Whereas the flexural yield strength increment was observed as 123 %, 150 % and 228 % for Sodium chloride (NaCl), Hydrochloric acid (HCl) and Sulfuric acid (H_2SO_4) respectively.

4. CONCLUSIONS

Both tensile and flexural properties were evaluated for the fabricated Kevlar/carbon fiber reinforced composite samples. The following conclusions were drawn from the results of both tensile and flexural tests, mentioned below:

- Soaking the specimens in chemicals influenced the mechanical properties of the Kevlar/carbon fiber reinforced hybrid composites.
- Chemical absorption of the composite samples decreased the yield strength, tensile strength and tensile modulus, but increased the elongation of the composite samples before breakage.
- Chemical absorption of the composite samples increased the flexural yield strength, flexural strength and deflection of the composite samples before breakage.
- The chemical absorption of the composite samples decreased the flexural modulus for both Sodium chloride (NaCl) and Hydrochloric acid (HCl), but whereas for Sulfuric acid (H_2SO_4) it is increased.

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AUTHOR'S PROFILE

M.Ramarao is full time Research scholar under JNTUA Ananthapuramu under the guidance of Dr. KL. Narayana and Prof. B. Durga Prasad. published two international journals in reputed publications. His current area of research includes Mechanical and Hygrothermal behavior of carbon epoxy composites optimization techniques and modeling .

Dr. KL. Narayana is a retired professor from SVU Tirupathi .present he is working as a eminent professor in SVCET, Chittoor. He written some text Books and he is well known Author for Engineering Drawing and Machine Drawing throughout India. He published more than 80 Journals in various international journals and his current area of research includes Composite materials

Dr. B. Durga Prasad is a Professor and controller of Examination (PG), Departmennt of Mechanical engineering, JNTUA University Ananthapuramu-515002. Andhra Pradesh, India. He has more than 22 years of experience in teaching and research and published more than 100 research publications in reputed journals. His current area of research includes alternative fuels for IC Engines, Thermal engineering. Machining of composite materials.